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Document 12.4
Work Enclosures and Local Exhaust Systems for Toxic and Radioactive Materials

Recommended for approval by the ES&H Working Group

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New document or new requirements

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☐ **New document**
☒ **Major requirement change**

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12.4

Work Enclosures and Local Exhaust Systems for Toxic and Radioactive Materials*

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Work Enclosures and Local Exhaust Systems for Toxic and Radioactive Materials

1.0 Introduction

This document contains requirements and provides detailed guidance to assist designers and users of contaminant control ventilation systems by identifying standards and good practices that need to be followed to ensure that contaminant control ventilation systems are designed, installed, maintained, and used successfully.

The application of Integrated Safety Management (ISM) to ventilation systems, including those with high-efficiency particulate air (HEPA) filters, is described in Document 2.1, "Laboratory and ES&H Policies, General Worker Responsibilities, and Integrated Safety Management," and Document 2.2, "Managing ES&H for LLNL Work," in the *ES&H Manual*.

The design and use of work enclosures used for toxic and radioactive materials shall be covered in the governing Integration Work Sheet (IWS). Ventilation systems designed for comfort are not covered by this document. Ventilation concerns related to biological safety are addressed in Document 13.1, "Biological Controls and Operations," in the *ES&H Manual*.

2.0 Controls for Compliance and Risk Reduction

2.1 Selection of Ventilation Systems

Ventilation systems generally consist of enclosures (e.g., hoods, gloveboxes, or shrouds) to draw contaminated air into the ventilation system, ductwork to convey the air, and a fan or other air moving device. Enclosing the contaminant source usually enhances contaminant control efficiency. The selection of a ventilation system design should be based on operational considerations such as:

- Ease of use.
- Containment of hazardous material in routine operations and in the event of an accident.
- Ability to protect users from inhalation and skin contact with hazardous materials.
- Ease of access to hood interiors during routine use and maintenance.
- Ability to contain an inert atmosphere, if required, for the experiment or job.

- Ability to handle overpressures and fires that might occur.

2.2 Effluent Concerns

The venting of effluents (new or modified) will require a National Environmental Policy Act (NEPA) review and possibly an air permit or abatement device to safeguard the public and environment. In addition, monitoring or quantification of the effluent may be necessary to determine fence-line concentrations for National Emission Standards for Hazardous Air Pollutants (NESHAPs), New Source Review and Air Toxics regulatory requirements. See Document 3.6, "Environmental Planning," and Document 31.1, "Air Quality Compliance," in the *ES&H Manual*, or your ES&H Team for additional information.

Even occasional use of solid highly hazardous materials in a hood may require high-efficiency particulate air (HEPA) filtration of the stack effluent. The effluent from gloveboxes that are used for handling dispersible solid toxic or radioactive materials is to be filtered, except for those using a recirculating unit described in Section 2.5 of this document. An ES&H Team evaluation will determine air cleaning requirements if only gases or vapors are present. Document 12.3, "Evaluation and Control of Facility Airborne Effluents," and Document 12.5, "High-Efficiency Particulate Air (HEPA) Filter System Design for LLNL Applications," in the *ES&H Manual* contain further information on exhaust system effluents and HEPA filters.

ES&H Team concurrence is required prior to operating ventilation systems that recirculate contaminated air from local exhaust systems to work areas. The ES&H Team may approve of recirculation in extremely limited situations where the contaminant is well characterized and thoroughly controlled. Precautions should include multiple air cleaning systems and automatic sensing devices that warn of air cleaner failure. Recirculation shall not be attempted if a malfunction could result in exposure levels that would cause worker health problems or in cases where recirculation is prohibited by regulations or standards.

2.3 Laboratory Hoods

Lab hoods are usually used for relatively low-hazard operations. Their suitability for work is determined during the completion and review of the IWS. The ventilation system pulls the air away from users and carries contaminants into the exhaust system. The open side is generally constructed with an adjustable transparent window that, when open, provides a large access area for equipment installation. When the hood is in use, the window should be partially closed to optimize protection. The vertically sliding sash should be positioned below the user's head and shoulders to provide a measure of blast and projectile protection for users. Workers using laboratory hoods shall verify that the hood is working properly in the following ways:

- The ES&H Team velocity check and flow visualization (smoke) tests are current as noted by a label on the hood.
- The fan is operating.
- The airflow indicators are functioning and are within appropriate ranges.
- There is no evidence that turbulence is sweeping contaminants out of the hood into the room air.

Responsible Individuals in laboratories should request a reevaluation of airflow from the area ES&H Team when making changes in the setup of experimental apparatus inside the hood. This is done by a smoke test.

Hood windows used to contain a blast or projectile hazards shall be made of rugged plastics, tempered glass, or reinforced glass to increase impact resistance. Impact resistant material does not have to be used if it can be ensured that the hood will never contain a blast or projectile hazard, in which case the hood shall be labeled to show that the window is not blast resistant.

An independent, local alarm system should be installed on all hoods and shall be installed on new hoods and on hoods involved in building modifications according to NFPA 45 ("Standard on Fire Protection for Laboratories Using Chemicals"). If the average fume hood face velocity falls below 60 feet per minute (fpm) or another set point designated by the ES&H Team industrial hygienist, the alarm should annunciate using a combination of audible alarm and a red light that continue until reset by an operator. The sensor should be accurate within ±5 fpm or a level designated by the ES&H Team industrial hygienist. Additional alarms may be needed for combination or multiple-sash hoods.

Labs containing work enclosures covered by this document shall be designed by organizations experienced in designing laboratories in accordance with the procedural requirements concerning client/designer/ES&H coordination specified in Document 12.2, "Ventilation," in the *ES&H Manual*. The design organization can demonstrate that it is capable of designing laboratory ventilation systems by having completed laboratory design projects that were accepted by the clients and found to be satisfactory or by familiarity with procedures and requirements applicable to laboratory design. This can be demonstrated if a design organization submits a list of previous clients who are interviewed to determine if the design organization did satisfactory work and the names of the designers and their previous experience on laboratory ventilation projects.

New fume hoods shall be standard products from a manufacturer chosen with the concurrence of the ES&H Team industrial hygienist. All new fume hood designs should demonstrate contaminant release less than 4.0 AM 0.05 according to ASHRAE Test Standard 110-1995 "Method of Testing Performance of Laboratory Fume Hoods".

2.3.1 Airflow

Hoods shall be designed to maintain an average face velocity of 100 fpm unless the area ES&H Team industrial hygienist concurs for sound technical reasons. Acceptable measured average velocities may range between 80 and 120 fpm per ANSI Z9.5-1995. An additional 10% of range can be granted on a once only basis to account for measurement uncertainties. The range of air velocities measured at one hood during a measurement session should not exceed ±20% of the average velocity. These specifications are summarized in Table 1.

Table 1. Acceptable face velocities for a laboratory hood.

	Performance criteria for measurements made at a single hood during a single measurement session	
	Average face velocity	**Face velocity range**
Acceptable results that can be repeated over a series of measurements	**80-120 fpm [a, b]**	**±20%[c] of the measured average velocity**
Acceptable results for a single measurement that cannot be repeated[d]	**70-130 fpm**	**As above**

[a] According to ANSI Z9.5-1995, a WSS, average velocities can range between 80 and 120 fpm while the *ACGIH Industrial Ventilation Manual*, a WSS, specifies a range between 80 and 100 fpm.

[b] Higher average velocities are recommended for hoods without coved or beveled openings and airfoil jambs on the bottom and in places where crossdrafts are a problem. The ES&H Team shall evaluate older hoods without airfoil jambs and coved entries on a case-by-case basis.

[c] ANSI Z9.5-1992 specifies the velocity range shall not exceed ±20% the average velocity.

[d] If the average velocity from the next set of measurements is also out of the 80-120 fpm band in the same direction as the first set of measurements, then the performance of the hood shall be taken to be unsatisfactory.

The area ES&H Team health & safety technician shall conduct measurements while the sash is set so it is half open, usually about 15- to 18-inches, unless the RI advises the sash is normally opened to a greater height. In those cases, the hood performance shall be checked when the sash is raised to the normal operating height identified by the operator. The height of 15- to 18- inches is low enough so the sash provides splash protection for the head and upper body, and high enough to usually allow work to be performed.. This may occur annually, following significant maintenance, at other times upon request, and before new or revised experimental setups are put in use. The area ES&H Team health and safety technician also performs smoke testing to indicate when hoods are working properly (i.e., to confirm that turbulence in the corners is not causing reverse flow, drag out, or incomplete capture). Smoke testing is also performed annually, following significant maintenance, at other times as requested, and before new or revised experimental setups are put in use. Workers using hoods and Responsible Individuals in laboratories are encouraged to take advantage of this service.

Equipment should not be placed near the opening of a hoodbecause it can cause turbulence that could disrupt the desired airflow pattern inside the hood.

Airflow under positive pressure shall not be introduced into the hood behind the plane of the hood sash or the ductwork connected to the hood without the concurrence of the ES&H Team industrial hygienist. An example would be a booster fan for a small appliance connected to the hood by a length of flexible duct. Other modifications to hood configuration shall not be made without the concurrence of the ES&H Team industrial hygienist.

2.3.2 Airflow Monitoring

Mandatory compliance with NFPA 45 requires installing quantitative airflow gauges on all new hoods and hoods in laboratories undergoing modification.

Continuous airflow monitoring gauges shall also be installed on ventilation systems that exhaust highly hazardous materials or where the nature of the operation would present unacceptable hazards if the system malfunctioned. The gauge sensors shall be located on the hood throat, across filters in the exhaust system, or other appropriate locations. The monitoring results should be quantitative where possible.

Monitoring gauge readouts should be installed in a location where users can readily observe the system's performance. These devices can be pressure gauges located between 2 and 4 duct diameters downstream from the hood or velocity sensors located in the hood's face or side. Further details on airflow monitoring are available in Chapter 9 of the *ACGIH Industrial Ventilation Manual*, from the area ES&H Team industrial hygienist, or the industrial hygiene subject matter expert.

2.3.3 Housekeeping

The following housekeeping rules shall be observed for hoods used to protect employee health:

- Unused equipment or equipment that will not be used in the immediate future shall be removed from the hood. Clutter can cause turbulent airflow in the hood. Stored equipment may become contaminated or may contaminate a current experiment thereby causing an unnecessary decontamination or disposal problem.
- Any equipment or material removed from a hood shall be carefully inspected for radioactive contamination. Similar monitoring shall be instituted for chemical hazards using the best available practical techniques.
- Hazardous materials in a hood shall be clearly labeled so all hood users are aware of their presence (29 CFR 1910.1200 and .1450).

- Electrical equipment or appliances and plug strips shall be evaluated before being used in a hood in which flammable or corrosive materials are used. Electrical items can be spark sources that could cause fire or explosion, and repeated exposure to corrosives will lead to damage that increases the hazard of electrical shock.
- Where practical, the hood floor shall be protected by a disposable plastic sheet covered with a layer of absorbent material.
- Whenever possible, equipment shall not be placed closer than 6 inches behind the face of a hood. Equipment close to a hood opening may cause turbulence that could affect the desired airflow pattern into the hood.

2.3.4 Room Design Considerations for New Laboratory Ventilation System Installations

The general ventilation system shall be designed to replace exhausted air and provide the temperature, humidity, and air quality required for the laboratory procedures without creating excessive drafts at exhaust hoods. The design features in this section apply to new ventilation systems that include laboratory hoods. They do not apply to a ventilation system that will be connected to an existing system or in locations where a new system will aerodynamically interfere with the operation of an existing system unless it is practical to upgrade the existing system to meet these design features. However, these design features should be applied to upgrades of existing hood installations when practical.

Makeup Air Location. Makeup air should be at the opposite end of the laboratory room from the fume hood(s). The velocity of supply air shall be no more than 40% of fume hood face velocity; 30% or less is preferred.

Makeup Air Quality. Supply air should meet the requirements of the latest version of ASHRAE Standard 62 (Indoor Air Quality).

Room Air Exhaust. Air exhausted from the general laboratory space (not from the exhaust hoods) shall be exhausted in a safe manner to outside the building; it shall not be recirculated. Wherever it is practical and safe to do so, the general laboratory room exhaust shall be combined with the fume hood exhaust through a manifold into a single system.

Supply Air Distribution. Supply air distribution should completely sweep the room, and exhaust through either the fume hood or general room exhaust system. In laboratories with very small hood exhaust volumes, this may be achieved by correct selection and placement of off-the-shelf supply air diffusers. In rooms with a large number of hoods, special low-velocity diffusers specifically designed for laboratory use are usually necessary. The supply air diffusers should be placed so that supply air reaches all parts of the laboratory space, thus ensuring highly effective ventilation.

Pressurization of the Laboratory Space. The makeup air should be introduced so that negative pressurization is maintained in all laboratory spaces and shall be introduced in a manner that does not create a disruptive air pattern. To maintain negative pressurization, the replacement air from the ventilation system at full volume should be 90% of the air removed from the lab space. The remainder of the air needed for makeup of the exhaust shall be drawn in from adjacent spaces, creating the required negative pressurization. This 10% of full design airflow should be a constant offset. Additional negative pressurization air may be needed in some cases when required by the area ES&H Team industrial hygienist.

Experience shows that the most appropriate supply air configuration into the lab is multiple perforated air diffusers located as far from the fume hoods as practical.

Airflow. As a general rule, airflow shall be from areas of low hazard to areas of high hazard. For high hazard locations, an anteroom or vestibule is required to maintain required pressure differentials. This is needed to implement NFPA requirements that chemical and radiation laboratories be at negative pressure. For low hazard areas (e.g., Radiological Type 1) the vestibule, if built, shall have a negative pressure with respect to both the hallway and the room. For higher hazard areas (e.g., places where ventilation devices such as lab hoods or gloveboxes are needed to protect workers including Radiological Type 2 and 3 workplaces) the room shall be negative with respect to the vestibule. In these areas, and others where flow from one area to another is critical to emission and exposure control, airflow monitoring devices shall be installed to signal or alarm a malfunction.

System Diversity. The maximum variable air volume diversity for design purposes should be 60%. This is a maximum of 40% reduction in total supply and exhaust air volume and heating and cooling capacity. The maximum diversity in the operation of the supply air and exhaust air systems should be determined by the sum of the minimum operational ventilation rates for each room.

Control Systems. Pressure-independent constant-volume or variable-volume air valves for supply and exhaust should be provided for pressurization control and continuous air balance control. The air balance should also be maintained during night setback and unoccupied schedule.

The volume of air exhausted by a constant face velocity fume hood varies with sash height. The associated control system shall be able to maintain the average fume hood face velocity at the set point (100 fpm) ± 10% under all operating conditions. The associated room pressurization controls shall maintain the laboratory at a negative pressure by modulating the supply air to maintain a constant face velocity. Fume hoods should be specifically made by the manufacturer for this use with consideration given to the limitation or elimination of the fume hood bypass area.

Laboratories with fume hoods should have a control system that monitors and controls the fume hood airflow, general exhaust, supply airflow, and room temperature. The control system should constantly monitor the amount of supply and exhaust air for the room and regulate the flow to maintain a net negative pressurization in the laboratory by continuously exhausting slightly more air than is supplied to the space.

The control system should allow easy, remote adjustment of laboratory airflow. It should be sufficiently flexible to provide timed schedules, local override, reduction of setbacks, or increase of room ventilation if needed for proposed laboratory operations.

The control system should perform the following functions:

- Monitor the hood sash opening and control the airflow to maintain a constant face velocity.
- Monitor the room occupancy to provide 100% of operational volumetric flow rate when space is occupied, regardless of hood use.
- Provide an unoccupied mode of operation not less than 60% of occupied operational levels.
- Monitor the fume hood exhaust airflow, the general exhaust airflow, and the supply (makeup) airflow, and maintain a net negative airflow equal to 10% of the maximum exhaust airflow.
- Maintain room temperature by regulating the supply airflow and room reheat coil.
- Monitor the building air balance (supply and exhaust).
- Provide central monitoring of the fume hood and laboratory systems, including
    - Room occupancy.
    - General room and fume hood exhaust air volume.
    - Supply air volume.
    - Fume hood sash position.
    - Low face-velocity alarm.
    - Space temperature.
    - Unoccupied temperature setback.
    - Unoccupied ventilation rate control for laboratories without fume hoods.

The control system should provide control of the ventilation rate in laboratories during occupied and unoccupied periods.

All laboratories where any hazardous chemicals or radionuclides are used shall have at least 10 air changes per hour whenever occupied, regardless of hood use. The system will allow up to 12 air changes per hour for high hazard areas, and may be adjusted to lower levels for nonhazardous areas such as library, offices, and lunchroom.

When a wet lab is unoccupied, the number of air changes can be reduced to no less than 6 air changes per hour for energy conservation, if it is safe to do so. At all times, the proper pressure ratio of lab to corridors shall be maintained when the ventilation system is operating.

2.3.5 Interior Configuration and Design Features

It is strongly recommended that new hoods be procured which have the following features:

- At least two, or preferably three, slots and baffles along the top and rear interior surfaces, either adjustable or fixed, to attain a reasonably uniform face velocity under various conditions of hood use.
- Vertical and combination vertical/horizontal fume hood sashes that move in the vertical direction with $\leq$2 lb force and stay in place when force is removed. Horizontal movement sashes with a minimum of two tracks (one or more panels per track) that require <2 lbs force to move.
- Spill retention provided by a recessed or "dished" work surface 1/2 inch or more below the front edge of the bench and a seamless vertical lip 1/2 inch high at the sides and back of the bench, or by another means of spill retention.
- A rounded airfoil with a gap of approximately 1 inch between the foil and the corner of the bench at the front edge of the bench, external to the sash and side posts of the front face tapered at approximately 45° for the height of the sash opening, or another method of smoothing airflow at the hood face.
- Rigid, safe, double wall construction, with a top.
- A transparent movable sash constructed of shatter-resistant, flame-resistant material that can close the entire front face of the hood. Sashes for new hoods shall be shatter-resistant. Sashes for existing hoods that are not shatter-resistant shall be labeled to show they are not shatter-resistant and operations involving deflagration, explosion, implosion, or pressurized equipment shall not be conducted in those hoods.
- Adequate lighting. Lights for new hoods shall be replaceable and maintainable from outside the hood.

- Valves and switches for utilities serving the hood placed at readily accessible locations outside the hood, including any three-pronged receptacles for 110 V AC power.
- Individually trapped sink or cup sink, if needed.
- Indicator lights for the electrical switches.
- Smooth and impermeable interior surfaces with rounded corners. Interior surfaces are as free of cracks and crevices as possible to provide easy cleaning in the event of an accident.

In addition, under-hood storage units should meet the following requirements:

- Units intended for chemical storage shall minimally contain recessed floor, metal lining, liquid and gas-tight construction, and ventilation flow from outside of the hood, through the storage unit, to the hood plenum chamber. Provisions should be made to include such storage units under all fume hoods.
- Units intended for flammable materials shall be approved by UL or Factory Mutual.

2.3.6 Unusual Operations

All operations of an unusual nature (for example, using perchloric acid or generating explosive concentrations of materials) shall be carefully evaluated before the decision is made to use a hood as a hazard control measure. Hoods provide only limited protection. Perchloric acid hoods shall have special features and be constructed of compatible material. See Document 14.8, "Working Safely with Corrosive Chemicals," in the *ES&H Manual*. The area ES&H Team shall be consulted when the characteristics or behavioral patterns of material to be used in a hood are not thoroughly known to the experimenter.

2.3.7 Fire Protection

Fire protection/suppression features will be required for some installations, as dictated by Work Smart Standards (WSS). The construction materials and the flammability levels of vapors shall be evaluated. Consult the fire protection engineering subject matter expert of Hazards Control for specific guidance.

2.3.8 Using Hoods for Storage

Hoods shall not be used for long-term storage of materials and equipment merely as a matter of convenience. A hood can be used for storage provided:

- It is in adequate condition with sufficient airflow for the purpose.
- It is labeled as a storage hood.
- The containers are sealed.
- The materials are compatible.

2.4 Gloveboxes

Gloveboxes are normally used for handling highly hazardous materials or when an inert or special atmosphere is required to control chemical reactions or fire. The pressure inside a glovebox is generally kept negative with respect to room pressure so that any leakage or non-catastrophic failure of the enclosure will result in a substantial inflow of air through the opening. For certain operations, positive pressure boxes are designed to prevent intrusion of moisture or external contamination. The area ES&H Team shall evaluate such boxes before procurement action is initiated.

New gloveboxes should be designed in accordance with the American Glovebox Society *Guideline for Gloveboxes* (with the exception of the airflow criteria that are given here). Gloveboxes should be fabricated by a source already established in the glovebox industry to avoid fabricating problems such as sealing difficulties that arise from deformations created during fabrication activities such as welding and grinding.

Those who use gloveboxes, other than those described in Section 2.5 of this document, shall take Course HS6390 “Introduction to Glovebox Safety”. Workers who change gloves or do other work that could cause them to breach the containment created by a glovebox shall rehearse new or unfamiliar operations using a similar, but uncontaminated, glovebox whenever practical.

2.4.1 Design Criteria

DOE Order 6430.1A (General Design Criteria) was rescinded and no replacement has been issued. Pending the adoption of glovebox design standards which are suitable for direct citation in engineering specifications by the American Glovebox Society, the following design criteria are still valid and apply to enclosures used to physically separate hazards from personnel, including hoods and gloveboxes, as well as enclosures and conveyor tunnels:

- Use of noncombustible or fire-resistant and corrosion-resistant materials for the enclosures and component parts. A fire risk analysis shall be completed by an organization with the concurrence of the DOE Fire Protection Authority to determine if the combustible loading in a fire area exceeds the fire rating of the structural components.

- Separation of discrete workstations by barriers to prevent fire spreading, based on safety analysis review.
- Consideration of heat generation.
- Automatic fire suppression.
- Ability to maintain confinement, including leak tightness (except for open-faced hoods).
- Standardized windows and mountings sized large enough to allow viewing of work, but not any larger.
- Standardized glove ports.
- Standardized provisions for cleaning, (e.g., rounded corners, smooth interior and exterior surfaces, minimal protuberances, and accessibility of parts).
- Standardized connection lines for service lines, conduits, instrument leads, and ductwork.
- Fire barriers.
- Sample removal ports.
- Pressure differential displays.
- Attachments for interconnections of enclosures.
- Window and glove fittings that allow replacement in a manner that minimizes potential exposures to hazards.
- Closure devices or permanent seals for penetrations through enclosures.
- Means of transferring items in and out of the enclosure.

The following requirements apply to auxiliary systems associated with gloveboxes based on lessons learned from a glovebox failure and Pu238 exposure incident in which a compression fitting was only finger tight and the Teflon seats of a ball valve had degraded in the harsh service environment. Harsh service environments can be radiological, chemical, or thermal.

- Ensure that compression fittings are assembled in accordance with the manufacturer's recommendations and guidelines.
- Ensure post-installation maintenance and testing is completed to verify joint integrity, and is performed in accordance with the manufacturer's recommendations and guidelines.
- Ensure the number of joints in mechanical systems is minimized.

- Implement a periodic inspection and replacement program to ensure component replacement prior to failure. This and the following two requirements apply particularly to Teflon, but would apply to polymers in other harsh service environments as well.
- Ensure the design criteria carefully evaluates the selection of components in radiological service.
- Consider using radiation-resistant sealing materials or seals composed of metal-to-metal surfaces.

2.4.2 Airflow Criteria for Atmospheric, Negative Pressure Glovebox ("Berkeley Box")

The average face velocity of air flowing into the door port shall be $\geq$50 fpm. The door area shall not exceed 1.5 square feet and hinged doors should not be used for new gloveboxes of this type. The ventilation provided should also be adequate to maintain an inward velocity of 125 fpm through a single glove port opening in case a glove is inadvertently removed or ruptured. The air exchange rate should be 10 to 20 air changes per hour. An air exchange rate shall be maintained to keep flammable vapor concentrations below 20% of the explosive limit, based on the rate of vapor generation. The box should be designed to maintain a negative pressure of 0.25 in. w.g.

A negative pressure of 0.25 in. w.g. is sufficient for typical radiological operations and operations involving the handling of toxic materials. Higher negative pressures, up to the limit appropriate for the box, may be used to obtain higher air exchange rates in some cases.

2.4.3 Airflow Criteria for Atmospheric/Inert/Dry Glovebox with Antechamber or Antechamber plus Gloved End Port

The average face velocity of air flowing into the end port or antechamber shall be $\geq$50 fpm. The size of the air lock port door should not exceed 1.5 square feet for gloveboxes with antechambers or 2.25 square feet for gloveboxes with a gloved end port. The ventilation provided shall also be adequate to maintain an inward velocity of 125 fpm through a single glove port opening in case a glove is inadvertently removed or ruptured. An air exchange rate shall be maintained to keep flammable vapor concentrations to less than 20% of the explosive limit for gloveboxes filled with air or other oxygen-containing mixtures, based on the rate of vapor generation.

The box should be designed to maintain a negative pressure of 0.25 in. w.g. The following exceptions may be made:

- Inert atmospheric boxes where operation at this negative pressure would cause undue consumption of gas. Then the minimum negative pressure should be 0.1 in. w.g., as long as there is no generation of flammable vapor or gas, or high levels of very toxic or corrosive materials.

- Flow and pressurization specifications shall be developed on a case by case basis with support from the area ES&H Team for boxes that contain flammable gases/vapors, or high levels of very toxic or corrosive materials.

A negative pressure of 0.25 in. w.g. is sufficient for typical radiological operations and operations involving the handling of toxic materials. Higher negative pressures, up to the limit appropriate for the box, may be used to obtain higher air exchange rates in some cases.

Inert gas gloveboxes should be equipped with air locks. Air locks should be equipped with automated pump-down and purge systems.

Air refill boxes of this type typically have sufficient airflow when sealed and operated at 0.25 in. w.g. negative pressure to prevent the dangerous accumulation of flammable, toxic, or radioactive contaminants in the air in the box. However, inert or dry gas boxes often have much lower gas flows to conserve the gas. It is advisable to verify the dilution rate inside the box while the box is sealed, especially where flammable vapors will be generated., For atmospheric refill boxes, clogging of the air inlet filter may result in unacceptably low flow rates when the box is sealed.

2.4.4 Other Glovebox Design Criteria

The IWS shall identify those situations where a detailed analysis shall be conducted to determine airflow and ventilation system requirements, due to a credible catastrophic failure (e.g., loss of a window in a glovebox used to contain hazardous or radioactive materials).

Exhaust air from gloveboxes containing toxic or radioactive material that may generate airborne particulates shall be filtered by a HEPA filter. A second HEPA filter, in series, shall be used for radioactive materials in Type III operations or if the effluent from Class II radiological operations cannot be discharged clear of building-induced turbulence in accordance with Document 12.3. HEPA filters that can handle the maximum required airflow shall be chosen. HEPA filters may also be needed for air locks and shall be provided for gloved air lock openings. See Document 12.5 for requirements concerning HEPA filters. A HEPA filter may also be required in the box's air supply port to prevent loss of material from the inside of the box to the room during overpressurization.

Flammable, toxic, or radioactive gases, vapors, or particulates that are generated by a single operation in a glovebox should be captured at the source and either removed from the box directly (e.g., a cup hood over an acid digestion) or scrubbed before releasing them into the box (e.g., perchloric acid vapor scrubbed using a basic solution).

This can reduce the need for high negative pressures and high dilution flow rates into the box.

Inert gases should be delivered to the glovebox location as gases rather than liquids to reduce the risk of developing an oxygen deficient atmosphere in the room if the gas delivery hardware of the glovebox leaks. The quantity of replacement gas shall be minimized consistent with operational needs. The ES&H Team industrial hygienist shall evaluate the need for room oxygen monitoring for locations where inert gas gloveboxes are to be installed. These requirements do not apply to dry air gloveboxes.

Ports used to introduce and remove items may be double-doored air locks in smaller gloveboxes or large bag-covered ports in larger gloveboxes. On new gloveboxes, these ports shall be designed to prevent the loss of negative pressure within the box while the port is in use.

Gloveboxes should be well lit from the outside. "Shadowless" illumination, like that provided by fluorescent tubes, is generally suitable.

2.4.5 Performance-Monitoring Gauges and Low-Performance Annunciation

The performance of fans or air movers connected to gloveboxes shall be monitored and the monitor should cause an audible and/or visible annunciation in a routinely occupied location if performance falls below a predetermined level.

Ventilation flow monitoring devices (such as Magnehelic gauges) and exhaust flow controls (such as dampers or rheostats) shall be installed. The instrument should have either a direct readout, prominently marked to show the reading of 0.25 ins. w.g., or an alarm set to sound if the pressure falls below 0.20 ins. w.g. The following should be located where the user can easily see and use them:

- The display for the performance monitoring instruments or, alternatively, a glovebox ventilation status display.
- Controls so the user can make flow adjustments while using the glovebox.

2.4.6 Using Gloveboxes

Glove ports shall be capped when not in use because glovebox failures usually occur at the glove ports. Glove flexing and deterioration due to atmospheric ozone, incompatible chemicals, and radiation in the box reduce normal glove life. Experience based on previous glove failures usually dictates the useful safe life of gloves. The IWS used to authorize work in a glovebox shall identify the glove inspection and replacement schedule.

The area ES&H Team shall make a hazard evaluation before flammable materials are used in a glovebox. As a rule, these materials shall be avoided or the quantities kept to minimum practical amounts.

For gloveboxes housing radiological materials, pass-in and pass-out ports shall be monitored for radioactive contamination after each use. The IWS will establish when similar monitoring is to be performed for chemical hazards using the best available practical techniques.

Before a box is used, the performance-monitoring gauges and controls shall be checked to ensure the box is in safe operating condition.

If an inert gas environment is required in the box, care shall be exercised during all purging operations to ensure that the internal pressure in the box is maintained negative to room pressure. An airflow gauge shall be installed to indicate whether the exhaust is adequate for the box design and its current use.

2.5 Recirculating Hoods

Small turnkey hoods and gloveboxes with HEPA or absorbent-bed filtered recirculating ventilation have become popular because they save energy and are convenient. The area ES&H Team shall review all plans before procurement actions are taken. These hoods can be used for particulate control, but shall not be used for handling highly hazardous materials or materials that create flammable vapors unless *both* of the following conditions are met:

- The specific uses, materials, and quantities have been evaluated and concurred with by the area ES&H Team and will not be changed.
- Use of the device is limited to specific quantities of materials through the IWS or its referenced documentation [e.g., Hazard Assessment and Control Form (HAC), Safety Plan, or other document].

These ES&H Team evaluations include estimating if concentrations of vapors could reach flammable or toxic levels and determining the flow rate to be maintained when access panels or air locks are opened. Glovebox users shall take Course HS6390, "Introduction to Glovebox Safety."

Some recirculating hood systems are sold with carbon canisters to absorb organic vapors. The device shall be evaluated as if the carbon canister was not present because the carbon canister's lifetime is unpredictable under varying conditions of use and some compounds from the carbon may be desorbed. The exception is if the conditions listed in the two bullets above are met and the glovebox manufacturer provides information that can be used to accurately estimate absorbent lifetime for the conditions of use. The exception conditions must be included in the IWS.

2.6 Other Industrial Ventilation Systems

2.6.1 General Requirements

System ductwork shall have provisions for cleanout when the ductwork conveys dusts or mists, and provisions for easy replacement if the contaminant is corrosive. New systems should be equipped with flow-monitoring devices that are displayed in easily seen locations in the spaces served by the ventilation systems.

2.6.2 Spray Treatment (Spray Painting, Solvent Spraying, Spray Washing or Cleaning of Parts, Etc.)

Spray booths shall be designed and operated to comply with OSHA requirements [29 CFR 1910.94(c) and 1910.107] and the *ACGIH Industrial Ventilation Manual*.

New spray booths shall be located to avoid cross drafts by placing them so the front openings are away from the following:

- Vehicle and personnel doors.
- Vehicle traffic paths.
- Other ventilation systems that blow jets of air towards the front of the booth.
- Places where air is forced to turn abruptly when it enters the booth.

The average air velocity in the booth shall be 150 fpm for small bench-top booths. The average velocity in the booth shall be 100 fpm for large walk-in booths with the following exception. The average air velocity in a large booth shall be ≥75 fpm if smoke testing reveals that the airflow in the booth is uniformly front to back at the places in which work pieces are located. When cross draft control was not considered and when existing booths are located where cross drafts are an issue, air velocities shall meet the requirements of OSHA, 29 CFR 1910.94(c), which are shown in Table 2.

The volume of air exhausted shall also be enough to keep the concentration of flammable solvent vapor less than 25% of its lower explosive limit (LEL).

Table 2. Air velocity requirements for spray treatment booths.

Booth Size	Cross Draft Velocity (fpm)	Average Air Velocity Requirement (fpm)	Range of Acceptable Air Velocities (fpm)

Small (bench top)	**>100**	**200**	**150–250**
	>50–100	**150**	**125–175**
	≤ 50	**100**	**75–125**
Large (walk in)	**>50–100**	**150**	**125–175**
	≤ 50	**100**	**75–125**

Spray booths shall be equipped with work piece hangers and bars, turntables, or other appliances appropriate for the work being done that allows painters to reposition work pieces as they work, so the time they spend in overspray-laden air is minimized. These appliances shall be kept in working condition. Painters shall be instructed to use them both verbally and in the documentation referenced in the authorizing IWS such as a shop procedure or Safety Plan. Work pieces shall be placed in spray booths so the time the worker spends in overspray-laden air is minimized.

Respirators shall be used when spraying two-component polyurethane coatings or coatings containing hexavalent chromium compounds such as zinc chromate or strontium chromate. An airline respirator or powered air purifying respirator shall be used unless the area ES&H Team industrial hygienist allows another type of respirator to be used by preparing a HAC. Refer to Document 11.1, "Personal Protective Equipment," in the *ES&H Manual* for additional respiratory and personal protective equipment requirements. Refer to Document 10.2, "LLNL Health Hazard Communication Program," in the *ES&H Manual* for workplace monitoring requirements.

Dilution ventilation may be used where aerosol cans or air brushes are used intermittently (equivalent to using one standard aerosol can per day at any given location) or where spraying is done on a non-routine basis using water-based paints that do not contain toxic or hazardous ingredients.

2.6.3 Welding

General. Air filtration of the exhaust may be needed, especially if the fumes contain toxic or radioactive materials. The opening of an exhaust system that is not filtered shall be discharged where it cannot re-enter buildings following Document 12.3 and Document 12.2.

Portable fume evacuators can be used, provided the design is appropriate for the toxicity of the material being welded. For example, cutting stainless steel can overwhelm portable electrostatic precipitators.

Natural Ventilation. Natural (convection) ventilation is acceptable only if all of the following conditions are met:

- Welding is limited to iron, mild steel, and aluminum.

- The distance from floor to ceiling is 16 ft or more.
- There are more than 10,000 ft^3 of air volume per welder that are not broken up by walls, equipment, or shields.
- The following are not present as base metals, fillers or coatings: antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lanthanide metals, lead, manganese, mercury, nickel, osmium, selenium, thallium, silver, vanadium, or zinc (stainless steels contain chromium and nickel) per ANSI Z49.1-1994. Contact your area ES&H Team industrial hygienist for guidance about other metals. In addition, organic coatings such as paints, primers, foams, and elastics shall not be heated with welding equipment. The odors of smoke and decomposition products from these coatings can make welders so nauseous that they may require medical attention. Additionally, the combustion products could be extremely toxic.

Mechanical (Area Exhaust) Ventilation. Mechanical ventilation can be used for welding iron, mild steel, and aluminum where adequate natural ventilation is not available (where there is less than 10,000 ft^3 of unobstructed air volume per welder or where ceilings are lower than 16 ft high). Mechanical ventilation may also be needed for stainless steel work other than oxygen cutting and brazing with cadmium-free alloys. Contact the area ES&H Team for guidance. Mechanical ventilation shall be applied using a fan exhausting at least 2,000 cfm per OSHA regulations. The fan should be located behind and above where the welding is performed.

Local (Close-Capture) Exhaust Ventilation. Local exhaust ventilation shall be used for welding, cutting, flame soldering, brazing using toxic or radioactive materials (other than thorium in electrodes) and oxygen cutting stainless steel unless it can be proven by air sampling that exposures are below applicable Occupational Exposure Limits. These toxic materials include:

- Antimony, arsenic, barium, beryllium, cadmium, cobalt, copper, lanthanide metals, lead, manganese, mercury, osmium, selenium, thallium, silver, vanadium, or zinc.
- Organic coatings.
- Cadmium in hard ("silver") brazing alloys or as a coating.

Exhaust ventilation for arc or torch welding can be provided using either a flexible exhaust duct or multi-slotted lateral exhaust hood system designed by a trained designer in strict accordance with the designs specified in the *ACGIH Industrial Ventilation Manual*. No other basic design is acceptable; *other designs have been tried at LLNL without success*. Flexible exhaust systems are commercially available. Local exhaust ventilation systems shall be able to maintain an air velocity of 100 fpm where welding fumes are generated. An exception is made for shielded arc welding where a flexible exhaust duct should be used with the duct opening being placed above and behind the source of welding fumes so the fumes and gases rising naturally are pulled into the suction opening. The preferred method for venting wire-fed shielded arc welders is the use of a shroud around the "gun"; such devices are commercially available. *Canopy hoods are not acceptable for welding.*

The guidance just given does not cover all uses of all welding materials; contact your area ES&H Team industrial hygienist for guidance on other situations.

Movable ventilators used for welding shall only be used with ES&H Team concurrence to ensure that they are used within their performance limitations.

2.6.4 Open-Surface ("Dip") Tanks

Open-surface tanks shall be ventilated as specified by the *ACGIH Industrial Ventilation Manual*. Each tank shall be ventilated at the appropriate rate specified in this manual; all tanks in a tank group should *not* be ventilated at the maximum rate for the worst-case tank in the group.

Tanks containing incompatible materials should be separated from each other so their spilled contents cannot mix. Tanks containing incompatible materials, such as acids and cyanides, shall be separated in this manner. Dikes, berms, or other features shall be installed to ensure that the spilled contents of acid tanks cannot mix with the contents of cyanide tanks. Acids and cyanides shall be stored separately. Ventilation for acids and cyanides shall be separate.

Safe worker practices for open-surface tanks shall be included in the Safety Plan or the shop procedure referenced in the authorizing IWS. See Document 14.12, "Safe Handling of Carcinogenic Materials," in the *ES&H Manual* for information about carcinogen controls.

2.6.5 Grinding Wheels and Belt Sanders

Ventilation shall be provided in accordance with the *ACGIH Industrial Ventilation Manual* at new installations and in accordance with OSHA regulations [29 CFR 1910.94(b)] at all installations.

Tools that are not suitable for grinding aluminum shall be conspicuously labeled using a DANGER label as specified in Document 12.1, "Access Control, Safety Signs, Safety Interlocks, and Alarm Systems," in the *ES&H Manual*.

OSHA regulations [29 CFR 1910.94 (b)] require air cleaners for grinding, polishing, and buffing tools. Air cleaners shall be checked at least monthly while the tools are in use and emptied when necessary. A HAC shall be prepared to specify protective clothing and procedures if the tool was used to abrade fiberglass, refractory ceramics, asbestos, lead, cadmium, chromium compounds found in paints and coatings such as zinc chromate, or other toxic or hazardous materials. A HAC is not required, but can be prepared, if the tool was used to abrade only steel, aluminum, or plastic. Refer to Document 10.2 for workplace monitoring requirements.

2.6.6 Abrasive Blasting

Ventilation shall be provided in accordance with the *ACGIH Industrial Ventilation Manual* at new installations and in accordance with OSHA regulations [29 CFR 1910.94(a)] at all installations.

Ventilation shall be sufficient to ensure that visible dust does not escape from abrasive blasting cabinet air intakes or access openings. The velocity of air entering makeup air openings of a large, walk-in, booth shall be ≥250 fpm. The velocity of air entering makeup air openings of a small bench top booth shall be ≥500 fpm.

Ventilation shall be applied in blasting cabinets after blasting has finished for a long enough period to remove visible airborne dust.

Sand (i.e., crystalline silica) shall not be used unless the ES&H Team industrial hygienist approves its use. Alternate grits that do not contain crystalline silica are widely available. An IWS and HAC are required for *any* sand blasting operation.

Dust accumulations on surfaces near abrasive blasting booths shall be promptly removed using the protective equipment and procedures specified in a HAC. Vacuuming or wet methods shall be used to remove dust when there is a question about the toxicity of the dust; compressed air nozzles shall not be used for this purpose.

OSHA regulations [29 CFR 1910.94(a)] require air cleaners and periodic static pressure monitoring. Air cleaners shall be checked at least monthly while the tools are in use and emptied when necessary. A HAC shall be prepared to specify protective clothing and procedures if the material being blasted contains fiberglass, lead, cadmium, chromium compounds found in paints and coatings such as zinc chromate, or other toxic or hazardous materials. A HAC is not required, but can be prepared, when the materials being blasted contain only steel, aluminum, plastic, or non-toxic paint chips. Refer to Document 10.2 for workplace monitoring requirements.

2.6.7 Other Industrial Operations

Other industrial operations, such as machining toxic materials or heating butyrate machine tool tip preservative, shall be ventilated if it can be demonstrated that ventilation will eliminate or substantially reduce overexposures to air contaminants or significant nuisances.

2.7 Toxic or Reactive Gas Cabinets

Ventilation requirements for toxic gas storage and handling are specified in Document 14.3, "Toxic, Corrosive, or Reactive Gases," in the *ES&H Manual*.

2.8 Storage Cabinets

Storage facilities used for extremely malodorous materials, materials stored in non-vapor-tight containers, and highly toxic materials should be stored in cabinets vented at a rate of at least 6 air changes per hour or 150 CFM, whichever is greater. Makeup air openings shall be provided unless the materials are flammable and need to be stored in a flammable storage cabinet. Makeup air shall be admitted on the side opposite the exhaust opening to maintain through-flow ventilation whenever practical. The makeup air opening shall have a flap or other device that closes if the exhaust ventilation is lost. See Appendix B for a list of materials that should be stored in vented cabinets.

Flammable storage cabinets should not be used to store materials that are not flammable because flammable storage cabinets are relatively more expensive than other storage spaces. Flammable storage cabinets may be vented provided that the:

- Venting arrangements do not compromise the fire resistance of the cabinet (this means only the vent bung connected to the exhaust duct can be opened).
- Exhaust duct is connected to the lower part of the cabinet.
- Ventilation rate exceeds one air change per hour, measured when a cabinet door is open. One door shall be open because the cabinet doors seal tightly to maintain fire resistance.

Ventilation requirements for the storage of toxic gases are addressed in Document 14.3.

2.9 Other Considerations

2.9.1 Emergency Power

Emergency power to exhaust fans is required for high-hazard operations to ensure nonstop performance of the exhaust and containment systems. Provisions for backup power are also recommended for other systems if a failure analysis or design basis accident evaluation reveals the potential for onsite or offsite harm. Criteria will be developed on a case-by-case basis by joint interaction of the program, Hazards Control Department, and Plant Engineering or other design organizations.

2.9.2 Energy Conservation

Design changes to existing local exhaust ventilation systems for the purpose of conserving energy shall be made with the concurrence of the area ES&H Team.

Controls and dampers, where required for balancing or control of the exhaust system (including VAV systems used for energy conservation in hoods), shall be a type that will fail to an open position in the event of failure to ensure continuous draft.

2.9.3 Seismic Safety

All work enclosures and local exhaust systems shall meet the seismic restraint standards developed by Plant Engineering.

2.9.4 Environmental Issues

NEPA documentation and air permit application may be required. An ES&H Team environmental analyst shall evaluate new operations and changes to existing configurations.

2.10 System Performance Measurements

Performance of ventilation systems shall be evaluated by measurement and using smoke testing when the system is installed and annually thereafter and by smoke testing on a quarterly basis. The ES&H Team industrial hygienist shall determine what measurements are needed for each system and assign acceptable performance criteria to each hood or system. Individuals responsible for ventilation systems and Responsible Individuals in laboratories should request measurements or smoke tests when they suspect that the performance of a ventilation system has changed. Performances of ventilation systems shall not be allowed to deteriorate from design specifications, the requirements of this document, or applicable WSSs, as appropriate unless the ES&H Team industrial hygienist gives written concurrence.

2.11 Canopy Hoods

Canopy hoods are usually ineffective because suction does not extend over distance. If effective, they potentially increase exposure to the contaminant if a worker places his or her head in the gap between the contaminant source and the hood. For these reasons, canopy hoods shall be used only to control minor nuisances, such as steam and cooking odors.

3.0 Responsibilities

All workers and organizations responsible for work enclosures and local exhaust systems for toxic and radioactive material shall refer to Document 2.1 for a list of general responsibilities. Specific responsibilities are listed below each title.

3.1 Workers

- Check hoods for proper functioning at the start of each work session and promptly report problems to the individual responsible for the ventilation system.
- Use hoods properly (e.g., positioning the sashes of lab hoods properly, keeping articles more than 6 inches from faces of hoods, verifying that lab hoods are working properly, using welding hoods properly, and using workpiece holder in spray booths).
- Complete required training.

3.2 Individuals Responsible for Ventilation Systems

- Contact the area ES&H Team for advice and evaluations when planning to install a new system, modify an existing system, change the process affected by a ventilation system, or whenever there is reason to believe system performance has changed.
- Arrange for correction of identified difficulties that occur with local exhaust ventilation systems.
- Contact the area ES&H Team for smoke testing of reconfigured hoods, evaluation of hoods being set aside for use as storage hoods, and evaluation of exhaust ventilation systems that may be malfunctioning or defective.
- Consult the area ES&H Team when the characteristics or behavioral patterns of material to be used in a hood are not thoroughly known to the experimenter or user.
- Contact the Facility Point of Contact to arrange for maintenance when necessary.

3.3 Work Supervisors

- Ensure that ventilation systems are used properly.

- Report problems with exhaust ventilation systems to the individual responsible for the ventilation system.
- With input from the area ES&H Team, determine who needs to take Course HS6390.

3.4 Responsible Individuals in Laboratories or Designees

- Arrange for smoke testing of laboratory hoods by the area ES&H Team when the configuration of apparatus in the hood is changed.
- Contact the area ES&H Team for evaluation of exhaust ventilation systems that may be malfunctioning or defective.

3.5 Facility Point of Contact

- Ensures that post-maintenance testing is performed to verify that the equipment functions properly.

3.6 Directorates

- Designate individuals who are responsible for ventilation systems by ensuring that exhaust ventilation systems are kept in working order and tested as specified in Section 3.2 of this document, including systems in locations where more than one group shares the equipment served by the ventilation system.
- Develop special flow and pressurization specifications for gloveboxes on a case-by-case basis with support from the area ES&H Team.

3.7 Hazards Control Department

3.7.1 ES&H Team

- Provides advice about air cleaning requirements using input from occupational safety and health and environmental protection representatives.
- Evaluates and smoke tests hoods when they are new, upon request, and periodically.
- Advises if materials are highly hazardous/toxic and warrant corresponding controls.
- Advises about emergency power needs in coordination with individuals responsible for ventilation systems and ventilation system design organization.

- Reviews and concurs with design changes to existing local exhaust ventilation systems for the purpose of conserving energy if safety is not compromised.
- Evaluates laboratory hood designs that maintain average air velocities other than those specified in this document or related WSSs and concurs that there are sound technical reasons for the change.
- Provides advice about precautions to be followed, including use of ventilation, when the characteristics or behavioral patterns of material to be used in a hood are not thoroughly known to the experimenter.
- Evaluates proposals to recirculate potentially contaminated air to work areas from local exhaust systems and concurs only if it can be shown that it will be safe to do so.
- Evaluates uses of movable welding ventilation systems.
- Evaluates NEPA documentation and air permit application requirements for new operations and changes to existing configurations.

3.7.2 ES&H Team Industrial Hygienist

- Determines alarm set points for lab hoods when the alarm set point needs to be a value other than 60 fpm or if the accuracy can be other than ±5% as specified in Section 2.3 of this document.
- Concurs with laboratory hoods selected by program management.
- Evaluates proposals to introduce airflow under positive pressure into a laboratory hood behind the plane of the hood sash or the ductwork connected to the hood and concurs if the installation will not compromise hood performance or safety.
- Evaluates proposals to modify the configuration of a laboratory hood and concurs if the modification will not compromise hood performance or safety.
- Evaluate the need for oxygen monitoring in places where inert gas gloveboxes are or will be used.
- Specifies respiratory protection for hazardous operations described in Section 2.6 of this document and authorized departures from the use of air line respirators for those applying two-component polyurethane paints as specified in Section 2.6.2 of this document.

- Provides guidance about the ventilation needed to weld materials not specifically addressed in Section 2.6.3 of this document.
- Specifically approves the use of silica sand for abrasive blasting as described in Section 2.6.6 of this document.
- Determines what measurements are needed for each system and assigns acceptable performance criteria to each hood or system.
- Advises if a material is highly toxic using MSDSs and other information based on accepted definitions of toxicity found in OSHA and elsewhere.
- Evaluates situations where hood performance has deteriorated and concurs, in writing, with continued use of the hood if there are sound technical reasons to do so.

3.7.3 Emergency Management Division

- Provides guidance about fire protection or suppression features required by WSSs, the evaluation of construction materials, and the flammability levels of vapors.
- Provides guidance about acceptable performances for hoods, hood testing protocols; changes to WSSs; and good practice for the design, use, and testing of hoods and ventilation systems.

4.0 Work Smart Standards

29 CFR 1910.94, "Ventilation."

29 CFR 1910.107, "Spray Finishing using Flammable and Combustible Materials," January 1999.

American Conference of Governmental Industrial Hygienists (ACGIH) *Industrial Ventilation Manual*, *A Manual of Recommended Practice,* 23rd Edition, Cincinnati, Ohio (1998).

ANSI Z9.5-1992, "American National Standard for Laboratory Ventilation," Sections 5.7 and 5.8.

ANSI Z49.1-1994, "Safety in Welding, Cutting, and Allied Processes."

DOE O 440.1A, "Worker Protection Management for DOE Federal and Contractor Employees," Attachment 2, "Contractor Requirement Document," Section 1–11, 13–18 (delete item 18.a), 19 (delete item 19.d.3) and 22.

NFPA 45, "Standard on Fire Protection for Laboratories Using Chemicals."

5.0 Resources for More Information

5.1 LLNL Contacts

For further information or assistance, contact your area ES&H Team.

5.2 Other Sources

American Industrial Hygiene Association, Biosafety Committee (AIHA), *Biosafety Reference Manual*, Second Edition, Fairfax, Va. (1995).

American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc., *1993 ASHRAE Handbook - Fundamentals*, Atlanta, Ga. (1993).

ANSI Z9.2, "American National Standard Fundamentals Governing the Design and Operation of Local Exhaust Systems." American National Standard Institute, N.Y. (latest revision).

ANSI Z9.3, "American National Standard for Exhaust Systems-Spray Finishing Operations-Safety Code for Design, Construction, and Ventilation." American National Standard Institute, N.Y. (latest revision).

ANSI Z9.4, "American National Standard for Exhaust Systems-Abrasive Blasting Operations-Ventilation and Safe Practices for Fixed Location Enclosures." American National Standard Institute, N.Y. (latest revision).

DOE O 6430.1A, "General Design Criteria."

Appendix A

Terms and Definitions

4.0 AM 0.05	When the hood is tested in accordance with ASHRAE Test Standard 110-1995, the release rate of tracer gas is 4.0 liters per minute and the tracer gas concentration is found to be $\leq$0.05 ppm when the test is conducted by the manufacturer for the type of hood being procured "As Manufactured."
Bag out	The process of placing a plastic bag over a port in a glovebox wall, sealing the bag to the port, opening the port, removing articles from the inside of the glovebox, removing the bag, and sealing the bag.
Carcinogenic	Capable of causing cancer.
Canopy hood	A hood placed directly above a contaminant source.
Compatible (materials)	Materials that will not release hazardous energy or reaction products when mixed. Opposite of incompatible. For example, alcohol and water are compatible because they readily mix and the release of heat is absorbed by the water, which prevents spatter or ignition. Acids and caustics are incompatible because the released heat can cause spatter or even ignite flammables. Acids and cyanide salts are incompatible because deadly hydrogen cyanide gas is released when they combine.
Contaminant	An undesirable material present in the air.
Deterioration (of hood performance)	A reduction in a measured value critical to system function, such as face velocity of a lab hood or capture velocity maintained by the hood for an open surface tank.
Dilution ("general") ventilation	Adding large volumes of air by mechanical means (such as a fan) to a space where the air is contaminated so the contaminant concentration is reduced to acceptable levels.
Face plane	The plane through which all air entering a hood must initially pass.

Flexible duct	A length of duct made of flexible metal or elastomer so one end can be placed close to a contaminant source. Also known as an "elephant trunk."
Glovebox	A ventilated work enclosure that has no openings to the air outside of it except through holes normally filled by gloves and ports through which items can be moved via air locks, pass through ports, or through designated ports by bag out procedures.
Highly hazardous	Materials that are radioactive or highly toxic.
Highly toxic	Substances that are harmful by being carcinogenic, a reproductive hazard, acutely toxic (such as by chemical asphyxiation in the case of hydrogen cyanide), or toxic by some other means such as the brain, liver, kidney, or blood forming organ toxicity for lead.
Hood	The opening of a ventilation system that air enters to begin its passage through the ventilation system.
Laboratory	A place where small quantities of chemicals are used. This includes laboratories as defined in the Document 14.2, "LLNL Chemical Hygiene Plan for Laboratories," in the *ES&H Manual* as well as places where repetitive, small scale chemical work is done. Pilot plants are excluded from this definition.
Laboratory hood ("fume hood")	A ventilated work enclosure with one open side through which air flows. The height or width of the opening can be adjusted by a sash and/or door(s). Air velocity is highest at the front opening (face plane). Airflow is distributed inside the hood by means of a plenum at the back with slot-type openings. Unlike a spray booth, where air velocity is essentially constant from front to back, the velocity of air inside the hood decreases rapidly after it has passed through the face plane.
Lateral exhaust ventilation	A hood that draws air from the contaminant source in a direction away from the user roughly parallel to the plane of level ground.

Local exhaust ("close capture") ventilation	Ventilation applied as close as possible to the air contaminant source, which pulls the contaminant into the ventilation system before it can reach the user's location.
Mechanical ventilation	Any ventilation using mechanical aids such as fans or other air movers to move air in a controlled manner. In the case of welding, mechanical ventilation specifically excludes local exhaust ventilation that OSHA addresses separately.
Natural ventilation	Ventilation provided without mechanical assistance, usually by convection.
Significant nuisance	An air contaminant which is not hazardous due to its potential to cause injury or toxic effects, but which has an odor, taste, or appearance which is so distressing or difficult that it reduces performance or makes an area uninhabitable. An example is butyric acid, which has a nauseating odor.
Smoke test	Introducing a visible plume of particulate into an air stream, usually the air entering a hood, to determine if there is turbulence that sweeps the material from the inside of the hood into the air outside of the hood where the user is. Normally done using hydrochloric acid aerosol made by the contact of titanium tetrachloride, zinc oxychloride, or tin tetrachloride with air. Zinc stearate and fog made by dropping dry ice into water can also be used.
Spray (paint) booth	A ventilated work enclosure in which air enters through the front and travels at constant velocity through a channel that has about the same dimensions as the front opening towards the back. Air velocity is relatively constant as the air travels from front to back, unlike a lab hood where air velocity is highest at the face plane.

System Diversity	For design engineering purposes, the percentage of the maximum theoretical sum of the volumetric flow rates of air exhausted by a set of variable air volume hoods connected to a common exhaust ventilation system that will actually be exhausted by that set of hoods due to the variations in sash heights. For example, a cluster of variable air volume hoods served by a ventilation system have a combined sash area of 1000 ft^2 if the sashes are fully raised and the hoods are the primary means of exhausting the area. Assuming the hoods are designed to maintain an average face velocity of 100 fpm, the flow rate of the ventilation system could be set at 100,000 cfm. The designer can assume that the combined sash opening will actually be 60% of that area. This reduces the system flow rate to 60,000 cfm.
Water gauge (w.g.), (inches of)	A unit of measurement of modest barometric pressures. Used to describe the amount of vacuum applied to a glovebox or the suction applied by a ventilation system.

Appendix B

Chemicals That May Require Ventilated Storage

Extremely Malodorous Compounds (Examples)

- Mercaptans such as methylmercaptan, ethylmercaptan, 1-propanethiol, 1-butanethiol, 1-pentanethiol, 1-hexanethiol, 1-heptanethiol, 1-decanethiol, cyclohexanethiol
- Amines such as diethylamine, triethylamine, dimethylamine, trimethylamine, cyclohexylamine, diisopropyl amine, diethylenetriamine
- Pyridine
- n-Valeraldehyde
- Diethyl ether, isopropyl ether

Non-Vapor-Tight Containers

- Storage of manufacturers' containers that are designed to be vented or have non-vapor-tight lids (e.g., diethyl ether in metal cans with plastic press-on caps).
- Storage of any non-vapor-tight laboratory apparatus or secondary containers which contain volatile organics (e.g., flasks with ground glass stoppers, beakers with paraffin seals, any pressure vented equipment with the exception of common solvents stored in metal safety cans).

High Toxicity Materials (Examples)

These materials were selected based on the following criteria:

- They are flammable or combustible liquids.
- They have an Occupational Exposure Limit of 10 ppm or less, typically 5 ppm or less.

Acrolein	Carbon disulfide
Acrylonitrile	Bis-chloromethylether
Allyl alcohol (3-chloropropene)	Chloromethyl methylether
Allyl chloride	Beta-chloroprene
Aniline	Crotonaldehyde
Benzene	Dichloroacetylene
n-Butylamine	Dichloro ethyl ether
n-Butyronitrile	1,3 dichloropropene

Diglycidyl ether
Dimethylhydrazine
Epichlorohydrin
Ethyleneimine
Formaldehyde solutions
Hydrazine
Isobutyronitrile
Isopropylamine
Methylacrylonitrile
Methyl hydrazine
Methyl isocyanate
1-Octanethiol
Pentaborane
1-Propyn-3-ol
Propionitrile
Propylene imine
Tetraethyl lead
Tetramethyl lead
Trimethyl phosphite
Vinyl acetate
Vinylidene chloride

Flammable Materials That Probably Do Not Require a Vented Storage Cabinet if in Vapor-Tight Containers (Examples)

Acetic acid
Acetone
Amyl acetate
2-Butanone
Butyl acetate
Butanol
Chlorobenzene
Cumene
Cyclohexane
Cyclohexene
Cyclopentane
Dichloroethane
Dichloroethylene
Diethyl ketone
Dimethylformamide
Dioxane
Ethyl acetate
Ethyl acrylate
Ethanol
Ethylbenzene
Ethyl butyl ketone
Ethylene dichloride
n-Heptane
n-Hexane
2-Hexanone
MIBK
Isoamyl acetate
Isoamyl alcohol
Isobutyl acetate
Isobutyl alcohol
Isooctyl alcohol
Isopropyl acetate
Methyl acetate
Methyl alcohol
Methylcyclohexane
Methyl formate
Methyl isoamyl ketone
Methyl isopropyl ketone
Morpholine
Nitroethane
Nitromethane
n-Pentane
2-Pentanone
Petroleum distillates
n-Propyl alcohol
Propylene glycol monomethyl ether
Stoddard solvent
Styrene
Tetrahydrofuran
Toluene
Trimethylbenzene
Turpentine
VM&P Naptha
Xylene